SPECIFICATION

TITLE OF THE INVENTION

ELECTRON BOMBARDMENT HEATING APPARATUS AND TEMPERATURE CONTROLLING APPARATUS AND CONTROL METHOD THEREOF

BACKGROUND OF THE INVENTION

1. FIELD OF THE INVENTION

The present invention relates to a heating apparatus for heating a material, such as, a semiconductor wafer, etc., to be heated up to high temperature, and in particular, an electron bombardment heating apparatus of a type, in which accelerated electrons are collided or impinged upon a heating plate, thereby generating heat thereon, and it relates to such an electron bombardment heating apparatus, in particular, being superior in thermal stress-resistance, and also a temperature controlling apparatus and a control method of such the electron bombardment heating apparatus, enabling both; i.e., an increase of temperature with stability and a maintenance of steady temperature.

2. DESCRIPTION OF PRIOR ART

In processes for treating semiconductor wafers, etc., an electron bombardment heating apparatus of such a type, in which accelerated electrons are stroked or impinged upon the rear surface of a heating plate, thereby generating heat thereon, is widely used as a means for heating up a plate-like material, such as the semiconductor wafer, etc. In such the electron bombardment heating apparatus, thermions generated through conduction of electricity into a filament are accelerated under high voltage, to be impinged

upon the rear surface of the heating plate, thereby generating heat in the heating plate. And, a plate-like material mounted on that heating plate is heated up.

Fig. 6 attached herewith shows such the electron bombardment heating apparatus, relating to the conventional art. In this Fig. 6, though not shown in the figure, an upper portion of a stage portion 106 is located within an inside of a vacuum chamber, and a portion of a heating plate 102 is located within a vacuum atmosphere.

In a wall of the stage portion 106, there is formed a coolant passage 107, and through this coolant passage 107 flows a coolant therein, such as a water, etc., for example, thereby cooling down the stage portion 106.

On this stage portion 106, there is provided a heat-resistive member 101 for supporting a material to be heated (hereinafter, being called by a "heated material supporting member"), having the flat heating plate 102 thereon, on which a thin plate-like material, such as a silicon wafer, for example, can be mounted to be heated up, and within an inside thereof, there is defined a space being hermetically separated from the space of an outside thereof. In more details, the heated material supporting member 101 is closed by means of the heating plate 102 on an upper surface side thereof, while being opened on a lower surface side, thereby having a cylinder-like shape. A lower end portion of the heated material supporting member 101 is fixed, abutting on an upper surface of the stage portion 106, and it is also hermetically sealed by means of a vacuum seal member 108.

As a material for building up such the heated material supporting member 101 is used, for example, a heat-resistive silicon carbide impregnated with silicon, or a ceramic, such as, alumina (or aluminum oxide) or silicon nitride, etc. In a case where the heated material supporting member 101 is made of an

insulating material, such as the silicon-impregnated silicon carbide, for example, an inner surface of the heating plate 102 is metallized for forming a conductive film thereon, and this conductive film is grounded through the stage portion 106.

On the stage portion 106 is formed an exhaust passage 104, and the space defined within an inside of the heated material supporting member 101 is evacuated by means of a vacuum pump 105, which is connected to that exhaust passage 104, thereby bringing about a vacuum condition therein.

Further, within the inside of the heated material supporting member 101, there is provided filaments 109. Those filaments 109 are located behind the heating plate 102 of the heated material supporting member 101, and further reflectors 103 are provided in the rear side of the filaments 109, for the purpose of heat blocking. To those filaments 109 mentioned above are connected a filament heating electric power source 110. Further, between those filaments 109 and the heating plate 102 is applied acceleration voltage through the heated material supporting member 101 from an electron acceleration electric power source 111. However, the heating plate 102 is grounded, and therefore it is kept to be a positive potential with respect to those filaments 109.

In such the electron bombardment heating apparatus as was mentioned above, the thermions are discharged from those filaments 109, when conducting electricity into the filaments 109 from the filament heating electric power source 110 while also applying the acceleration voltage of a certain high voltage between the filaments 109 and the heating plate 102 through the electron acceleration electric power source 111, and those thermions are accelerated under the acceleration voltage mentioned above, thereby being impinged upon the lower surface of the heating plate 102. For this reason, the heating plate 102 is heated up due to the electron bombardment.

When the temperature of the heating plate 102 rises up, while measuring the temperature of the heating plate 102 due to the electromotive force generated in a thermocouple 112 by means of a thermometer 114, and when the temperature of the heating plate 102 reaches up to a predetermined value, the electric power supplied to the filaments 109 comes down in an electric power adjustor 117, thereby maintaining the temperature of the heating plate 102 at the predetermined value. And, when passing a predetermined time period, the electricity is stopped to be conducted into the filaments 109, thereby stopping the heat generation of the heating plate 102, while cooling is started by means of the coolant flowing through the coolant passage formed in the stage portion 106, thereby lowering down the temperature of the heating plate 102.

The heated material supporting member 101 is cooled down on the lower end surface thereof, through the coolant, such as the water, etc., flowing through the coolant passage 107 of the stage portion 106; e.g., via the stage portion 106. On the other hand, the heating plate 102 building up an upper wall of the heated material supporting member 101 is heated up, through the bombardment of the electrons, which are discharged from the filaments 109 and accelerated by means of the electron acceleration electric power source 111 of high voltage. For this reason, a steep thermal gradient is established, in particular, between the heating plate 102 for building up the upper wall of the heated material supporting member 101 and the lower end portion of the heated material supporting member 101 in contact with the stage portion 106.

However, the heated material supporting member 101 is made of, for example, the heat-resistive silicon carbide impregnated with silicon, or the ceramic, such as, alumina (or aluminum oxide), or silicon nitride, etc., therefore it is weak in the thermal stress. For this reason, when starting the heating of the heating plate 102, only the heating plate 102 for building up the upper wall of the heated material supporting member 101 shows the thermal

expansion. Accompanying this, the heated material supporting member 101 deforms, and the thermal stress is concentrated, in particular, upon a shoulder portion defined between a peripheral wall portion and the heating plate 102. And, if repeating such the heating and the cooling on the heating plate 102, the heated material supporting member 101 receives the thermal stress, repetitively, and therefore there is brought about a problem that it is fatigued and deteriorated, gradually, thereby resulting into breakage thereof.

BRIEF SUMMARY OF THE INVENTION

According to the present invention, by taking such the problems mentioned above in relation to the conventional electron bombardment heating apparatus into the consideration, an object is to provide an electron bombardment heating apparatus, with which the thermal stress can be relieved or mitigated, being generated due to the difference in temperature between the heating plate, which is heated through the electron bombardment of the heated material supporting member thereon, and the lower end portion of the heated material supporting member, which is cooled down through the stage portion. With this, the heated material supporting member is hardly fatigued even if repeating the heating and the cooling on the heating plate, thereby causing no breakage therein for a long time period.

According to the present invention, for accomplishing the object mentioned above, a heated material supporting member having a heating plate as a ceiling thereof is formed into, not a cylindrical shape having a single radius, but that having at least one (1) stage or more in a middle portion thereof. Namely, upper and lower portions of the heated material supporting member are made up with multi-staged periphery wall portions in a cylinder-like shape, being different in the radius thereof, and those periphery portions are connected with by means of a ring-like horizontal wall extending into the radial directions thereof. With this, thermal stress

caused due to the difference of temperature between the heating plate of the heated material supporting member and the lower end portion thereof can be mitigated, by means of the multi-staged periphery wall portions and the horizontal wall connected therewith, thereby protecting it from breaking in an early stage thereof.

Thus, according to the present invention, there is provided an electron bombardment heating apparatus, for heating a heating plate through bombardment of thermions thereon, comprising: a filament for generating thermions therefrom; means for accelerating the thermions emitted from said filament; a heating plate being heated through bombardment of the thermions, which are emitted and accelerated; and a heated material supporting member for mounting a material to be heated thereon, wherein a periphery wall of said heated material supporting member, being covered with said heating plate on a ceiling thereof, is made up with a plural number of stages of periphery wall portions disposed vertically, being different from each other in diameter thereof, and those periphery wall portions are connected with each other through a ring-like horizontal wall extending in radial directions thereof.

With such the electron bombardment heating apparatus, according to the present invention, since the periphery wall of the heated material supporting member including the heating plate as a ceiling thereof is made up with the multi-staged periphery wall portions, being different in the radius, in the vertical direction thereof, and since those periphery wall portions are connected with each other through the ring-like horizontal wall extending into the radial directions thereof, the thermal stress can be mitigated, by means of the multi-staged periphery wall portions and the horizontal wall connecting therewith, if the difference is caused in the temperature between the heating plate of the heated material supporting member and the lower end portion thereof, when heating. In particular, since the shoulder portion formed on the heated material supporting member, where the thermal

stress can concentrate thereupon, easily, comes to be more than (1) pieces, therefore it is difficult for the thermal stress concentrates on a specific shoulder portion. Accordingly, it is possible to bring the thermal stress to be small, which is applied upon the heated material supporting member as a whole, and even if repeating the heating and the cooling down to the room or steady temperature, it can be protected from breaking in the early stage thereof.

Further, according to the present invention, an insulator plate having high insulating property and heat-resistance, such as, a ceramic plate, etc., is inserted between the plural numbers of the metal reflectors. The reflector 3 below the insulator plate 20 is one, being provided for the purpose of heat insulation but without electrical connection, and the reflector(s) above the insulator plate 20 is/are one(s), having functions of both, i.e., preventing electrons from discharging to a rear side thereof, and the heat insulation.

Further, according to the present invention, in such the electron bombardment heating apparatus as was mentioned in the above, the thermal control when rising up the temperature and the thermal control when maintaining at the steady temperature are carried out by means of control methods separated from. In more details, when rising up the temperature, a total amount of energy of electrons impinging upon the heating plate is controlled to be a constant through controlling the electric power to be supplied to the filament while measuring the emission current, thereby maintaining the thermal gradient at the preset value. In addition thereof, the temperature of the heating plate is measured, and after the heating plate reaches up to the predetermined temperature, the electric power for conducting electricity to the filament by means of the measured value of temperature, thereby maintaining the heating plate at the predetermined value that is set in advance.

A temperature controlling apparatus, according to the

present invention, for achieving such the thermal control as was mentioned above, comprising: an electric power adjuster for controlling filament electric power to be supplied to the filament; an emission current adjuster, for measuring emission current flowing between the filament and the heating plate, and for outputting a measurement value of the emission current to said electric power adjuster as a control signal; and a thermal adjuster for measuring the temperature of the heating plate and for outputting the measured temperature value to said electric power adjuster as a control signal, wherein either one of said emission current adjuster or said thermal adjuster is selectively exchanged to be connected with the electric power adjuster, by means a switch.

A method for controlling temperature of the heating plate, by means of such the temperature controlling apparatus, including therein an electric power adjuster for controlling filament electric power to be supplied to the filament, comprising the following steps of: controlling emission current to be a preset value by means of said electric power adjuster, while measuring the emission current flowing between the filament and the heating plate by means of an emission current adjuster, when the temperature of the heating plate rises up; and also controlling the temperature of the heating plate to be a preset temperature by means of said electric power adjuster, while measuring the temperature of the heating plate by means of a thermal adjuster, after the measured temperature reaches to a preset temperature. In this instance, a switch is changed over upon a fact that the measured value of temperature measured by said thermal adjuster reaches to the preset temperature or temperature a little bit lower than the preset temperature.

With such the temperature controlling apparatus and the method for the electron bombardment heating apparatus, the emission current flowing between the filament and the heating plate is set in advance, and then when temperature of the heating plate rises up, said electric power adjuster is controlled by means of the

emission current adjuster so that the emission current comes to be constant while measuring this emission current. With this, it is possible to give a constant electron bombardment upon the heating plate per an hour, thereby obtaining a constant thermal gradient with stability.

At the same time, measuring the temperature of the heating plate by means of the thermal adjuster, the electric power adjuster is switched to the side of the thermal adjuster when temperature of the heating plate reaches to the predetermined one, thereby conducting the thermal control with feeding the temperature of the heating plate back to the electric power adjuster. With this, it is possible to maintain the predetermined temperature to be steady in condition, with accuracy and stability.

In this manner, with the electron bombardment heating apparatus according to the present invention, since the thermal stress accompanying thermal change is dispersed due to the plural numbers of stages of the heated material supporting member and the horizontal wall, the fatigue breaking hardly occurs thereon in spite of the thermal stress, which is caused by repeating the heating and the cooling repetitively. For this reason, it is possible to protect the heated material supporting member from being destroyed in the early stage, and thereby to obtain the heated material supporting member having a longer lifetime.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING

Those and other objects, features and advantages of the present invention will become more readily apparent from the following detailed description when taken in conjunction with the accompanying drawings wherein:

Fig. 1 is a vertical cross-section view of an outlook structure of an electron bombardment heating apparatus, for showing an embodiment according to the present invention;

Fig. 2 is a cross-section view of a principle portion of the electron bombardment heating apparatus, in particular, for showing a portion of a heated material supporting member thereon, in the embodiment mentioned above;

Fig. 3 is a graph attaching a chart therein, for showing an example of the relationship between time and temperature when heating up the heating plate, and also the chart of temperature control at that instance therein;

Fig. 4 is a vertical cross-section view of an outlook structure of an electron bombardment heating apparatus, for showing other embodiment according to the present invention;

Fig. 5 is a vertical cross-section view of an outlook structure of an electron bombardment heating apparatus, for showing further other embodiment according to the present invention, in which the structure of a reflector portion is changed; and

Fig. 6 is a vertical cross-section view of an outlook structure of the electronic bombardment heating apparatus, relating to the conventional art.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Hereinafter, embodiments according to the present invention will be fully explained, by referring to the drawings attached herewith.

Fig. 1 is a cross-section view of an outlook structure of the electron bombardment heating apparatus, for showing an embodiment according to the present invention, wherein an upper portion of a stage portion 6 is located within an inside of a vacuum chamber, and a portion of a heating plate 2 is within the vacuum atmosphere, in the similar matter of the conventional art, as was mentioned in the above by referring to Fig. 6.

In a wall of the stage portion 6 is formed a coolant passage 7, and the stage portion 6 is cooled down through a coolant, such as a water, etc., flowing through that coolant passage 7.

On this stage portion 6 is provided a heat-resistive member 1 for supporting a material to be heated (hereinafter, being called by "heated material supporting member"), having the flat heating plate 2 thereon, on which a thin plate-like material, such as a silicon wafer, etc., can be mounted to be heated up, and within an inside thereof, there is defined a space being hermetically separated from the space of an outside thereof. In more details, the heated material supporting member 1 is closed by means of the heating plate 2 on an upper surface side thereof, while being opened on a lower surface side thereof, thereby having a cylindrical shape, and a flat upper surface of the heating plate 2 is wider than the thin plate-like material to be heated up, such as, the silicon wafer, etc. A flange is provided at the lower end portion of the heated material supporting member 1, and this flange portion is fixed on an upper surface of the stage portion 6 abutting thereon, and it is hermetically sealed by means of a vacuum seal member 8.

The heated martial supporting member 1 is made of silicon carbide impregnated with silicon, or a ceramic, such as, alumina (or aluminum oxide) or silicon nitride, etc. In a case where the heated material supporting member 1 made of an insulating material, such as, silicon-impregnated silicon carbide, for example, an inner surface of the heating plate 2 is metallized for forming a conductive film thereon, and this conductive film is grounded through the stage portion 6. Also, the same object can be achieved, by including conductive materials within the material for building up the heating plate 2, so as to let it to show conductivity.

As is shown in Fig. 1, a periphery wall of the heated material supporting member 1 is large, in the diameter at a lower stage thereof, while being small in the radius at an upper stage thereof,

therefore, it has a cylindrical shape of two (2) stages. The periphery wall portion 13b being large in the radius at the lower stage and the periphery wall portion 13a being small in the radius at the upper stage are connected with, by means of a ring-like horizontal wall 5, extending into a radial direction of that periphery wall. Those periphery wall portions 13a and 13b, being different in the radius thereof, and also the horizontal wall 5 connecting them may be formed, preferably, in one body or as one unit.

In the stage portion 6 is formed an exhaust passage 4, and the space defined within an inside of the heated material supporting member 1 is evacuated by means of a vacuum pump 5, which is connected to that exhaust passage, thereby bringing about the vacuum condition therein.

Further, within an inside of the heated material supporting member 1, there are provided filaments 9 and reflectors 3.

The filaments 9 are provided in the rear side of the heating plate 2 of the heated material supporting member 1, and to those filaments 9 is connected a filament heating electric power source 10 through an insulator seal terminal. This filament heating electric power source 10 is insulated, so that voltage is high at a side of the filaments 9 while it is low at a side of a voltage adjuster 17. Furthermore, between the filaments 9 and the heating plate 2 is applied voltage for acceleration through the heated material supporting member 1, by means of an electron acceleration electric power source 11. However, the heating plate 2 is grounded, and it is kept at a positive potential with respect to the filaments 9.

The reflectors 3 are provided in the rear side of the filaments 9, with respect to the heating plate 2 of the heated material supporting member 1. This reflector is made of a metal having high reflectivity, such as gold (Au), silver (Ag), etc., or a metal

having high melting point, such as, molybdenum, etc. A surface of the reflector 3, opposing to the heating plate 2 of the heated material supporting member 1, is made from a mirror surface, thereby reflecting the radiant heat thereupon. Though being electrically insulated from the heated material supporting member 1, however those reflectors 3 are positioned under the potential condition of being about equal to that of the filaments 9. With this, no electron comes flying toward the reflectors 3, thereby causing no heating due to the electron bombardment thereupon. Such the filaments 9 can be disposed in duplicate.

In the central portion of the reflector 3, a shield 15 made from a cylinder-like conductor stands up, and this shield 15 and the reflectors 3 are electrically conducted with each other; i.e., being equal in the potential thereof. An upper end side of this shield 15 reaches up to the vicinity of the lower surface of the heating plate 2 of the heated material supporting member 1, while a flange is provided extending from the upper end portion of that shield 15 to an outside, and therefore this flange faces to the lower surface of the heating plate 2.

A sheath-type thermocouple 12 is inserted into vertically, from the central portion of the stage portion 6 mentioned above, as a temperature measuring element, and an upper end side of this is disposed within the shield 15 under the non-contacting condition thereon. The upper end of this thermocouple 12, connecting a pair of lines of thermocouple as a junction, builds up a temperature measurement point within the shield 15 mentioned above, and the temperature measurement point is in contact with the lower surface of the heating plate 2 via an insulator tube. The thermocouple 12 is wired out from the stage portion 6 into an outside of the vacuum chamber, and a compensation lead wire is connected to a thermometer 14 including a zero point compensation circuit therein.

With such the electron bombardment heating apparatus, the thermions are emitted from the filaments 9 when conducting

electricity to the filaments 9 by means of the filament heating electric power source 10, while applying a certain high voltage for acceleration between the filaments 9 and the heating plate 2, by means of the electron acceleration electric power source 11, and those emitted thermions are accelerated under the acceleration voltage mentioned above, and impinge upon the lower surface of the heating plate 2. For this reason, the heating plate 2 is heated up due to the electron bombardment thereupon. In this instance, the coolant flows through the coolant passage 7 formed in the stage portion 6, and thereby the heated material supporting member 1 is cooled down.

The temperature of the heating plate 2 rises up, while measuring the temperature of the heating plate 2 by means of the thermocouple 12, and when the temperature of the heating plate 2 reaches up to a predetermined value, then the filament heating electric power source 10 for conducting electricity to the filaments 9 is lowered down in the electric power thereof, and then the heating plate 2 is maintained at a predetermined temperature. When passing a predetermined time period, the electricity is stopped to be conducted into the filaments 9, thereby to stop the heat generation of the heating plate 2, while the cooling is stared by means of the coolant flowing through the coolant passage formed in the stage portion 6, thereby lowering down the temperature of the heating plate 2.

In this manner, the lower end portion of the heated material supporting member 1 is cooled down by means of the cooling water flowing through the coolant passage 7 formed in the wall of the stage portion 6, when heating up the heating plate 2. For this reason, a large thermal gradient is established between the lower end portion of the heated material supporting member 1 and the heating plate 2. On the other hand, before the time when heating up the heating plate 2 and during the time when cooling it, both the lower end portion of the heated material supporting member 1 and the heating plate 2 are in the vicinity of the room or steady

temperature, therefore there is established no thermal gradient therebetween. In this manner, with repetition of heating and cooling, a large change is caused on the thermal gradient established between the lower end portion of the heated material supporting member 1 and the heating plate 2, repetitively.

In this instance, as is shown in Fig. 2, though the heating plate 2 of the heated material supporting member 1, the upper and lower periphery wall portions 13a and 13b, and the horizontal wall 5 expand, and thereby deforming, respectively, however the expansion mentioned above can be absorbed by the walls neighboring with each other. Further, comparing to the conventional electron bombardment heating apparatus shown in Fig. 6 mentioned above, wherein the only one (1) piece of shoulder portion is defined between the heating plate 2 of the heated material supporting member 1 and the periphery wall portions, however according to the electron bombardment heating apparatus shown in Fig. 1, the shoulder portions are defined by three (3) in the pieces thereof, and therefore the stress concentrating upon the shoulder portions can be dispersed much more between them. With this, even if applying the heating and the cooling thereon, repetitively, it is difficult to cause the breakage, in an early stage thereof, due to the thermal stress applied thereon repetitively.

Next, the structure of a temperature controller for use of such the electron bombardment heating apparatus will be explained, by referring a block diagram, which is inserted into Fig. 1 mentioned above.

There is provided an electric power adjuster 16 for the purpose of adjusting current and voltage for heat generation to be supplied to the filaments 9, in other words, electric power of the filament heating electric power source 10 for supplying current for use of emission of thermions to the filaments 9.

Further, there are provided an emission current adjuster

17 for the purpose of outputting a control signal to the electric power adjuster 16, and also a thermal regulator 18.

The emission current adjuster 17 has a function of setting or determining the emission current flowing between the heating plate 2 side and the filaments 9 at a predetermined value. Furthermore, while measuring the emission current, this emission current adjuster 17 outputs a control signal to the electric power adjuster 16, so that the emission current is maintained at a predetermined preset value, thereby adjusting the current and the voltage of the filament heating electric power source 10 for conducting electricity to the filaments 9, by means of this electric power adjuster 16.

On the other hand, the thermal regulator 18 has functions of setting the steady temperature of the heating plate 2 at a predetermined temperature, and also of setting a time period for maintaining that steady temperature. Further, while measuring the temperature on the lower surface of the heating plate 2 by means of the thermocouple 12 and the thermometer 14 connected thereto, this thermal regulator 18 outputs a control signal to the electric power adjuster 16, so that the temperature of the heating plate 2 is maintained at the predetermined preset value mentioned above, thereby adjusting the current and the voltage of the filament heating electric power source 10 for conducting electricity to the filaments 9, by means of this electric power adjuster 16.

Also, the thermal regulator 18 actuates a switch 19 of a relay, etc., for example. During when the temperature rises up, but before the temperature measured in the thermometer 14 by means of the thermocouple 12 reaches up to the steady temperature, which is reset by means of the thermal regulator 18, the emission current adjuster 17 is connected to the electric power adjuster 16. Thereafter, when the temperature measured in the thermometer 14 reaches up to the steady temperature preset by means of the thermal regulator 18, the switch 19 is changed over, so that the thermal

regulator 18 is connected to the electric power adjuster 16.

Next, explanation will be given on a method for controlling the temperature of the electron bombardment heating apparatus, with aid of this temperature controller.

First of all, the emission current to be maintained at constant when temperature rises up is set up in advance, by means of the emission current adjuster 17, depending upon the thermal gradient when the temperature of the heating plate 2 rises up. Also, by means of the thermal regulator 18, temperature to be maintained at constant is set up in advance, depending upon an object of thermal treatment or processing of the material to be heated up.

When starting conduction of electricity into the filaments 9 through the filament heating electric power source 10, while applying the constant high voltage for acceleration between the filaments 9 and the heating plate 2, at the same time, by means of the electron acceleration electric power source 11, then the thermions are emitted from the filaments 9, and those thermions, being accelerated under the acceleration voltage mentioned above, impinge upon the lower surface of the heating plate 2. For this reason, the heating plate 2 is heated up due to the electron bombardment. At the same time, emission current flows through between the filaments 9 and the heating plate 2. In this instance, the acceleration voltage applied through the electron acceleration electric power source 11 is made constant.

During when the temperature of the heating plate 2 rises up, but before it reaches up to the steady temperature, which is set up in advance by means of the thermal regulator 18 mentioned above, the emission current adjuster 17 is connected to the electric power adjuster 16. This emission current adjuster 17, while measuring the emission current flowing between the heating plate 2 side and the filaments, outputs a control signal to the electric

power adjuster 16, so that the emission current is maintained at the preset value thereof, thereby adjusting the voltage and the current of the filament heating electric power source 10 for conducting electricity to the filaments 9, by means of this electric power adjuster 16. With this, the emission current flowing between the heating plate 2 side and the filaments 9 is maintained at the constant value when the hating plate 2 rises up the temperature thereof. As was mentioned previously, the acceleration voltage, which is applied by means of the electron acceleration electric power source 11, is constant, and also the emission current is maintained at the constant value. For this reason, the energy, given to the heating plate 2 due to the electron bombardment, comes to be constant, and the heating plate 2 rises up the temperature thereof, at a constant thermal gradient.

Thereafter, when the temperature of the heating plate 2 reaches up to the steady temperature, which is preset by means of the thermal regulator 18 mentioned above, the switch is actuated, so as to change over the contact thereof, and therefore, the thermal regulator 18 is connected to the electric power adjuster 16. This thermal regulator 18, obtaining or receiving the signal from the thermometer 14 for measuring the temperature on the lower surface of the heating plate 2 by means of the thermocouple 12, outputs a control signal to the electric power adjuster 16, so that the temperature of the heating plate 2 is maintained at the steady temperature, which was preset in the manner mentioned above, thereby adjusting the current and the voltage of the of the filament heating electric power source 10 for conducting electricity to the filaments 9, by means of this electric power adjuster 16. With this, the temperature of the heating plate 2 is maintained at the steady temperature preset. And, when passing the time period that is preset in the thermometer 14, the electricity is stopped to be conducted from the electron acceleration electric power source 11 to between the filaments 9 and the heating plate 2, thereby lowering down the temperature of the heating plate 2.

Fig. 3 shows an example of a relationship between the time and the temperature when heating up the heating plate 2, and also a chart for controlling the temperature in this instance.

As is shown in the figure, when the temperature rises up, i.e., from the time of starting the heat generation of the heating plate 2 up to the time of reaching to the steady temperature preset, the electric power of the filament heating electric power source 10 is controlled, so that the preset emission current comes to be constant, while measuring the emission current, so as to feed it back to the electric power adjuster 16. Since the energy given to the heating plate 2 due to the electron bombardment is determined by the product between the emission current and the acceleration voltage, therefore, with this control, due to the electron bombardment, a constant amount of energy is given to the heating plate 2 per an hour, when rising up the temperature of the heating plate 2.

On the other hand, after the heating plate 2 reaches up to the preset steady temperature, the electric power of the filament heating electric power source 10 is controlled, so that the preset steady temperature comes to be constant, while measuring the temperature of the heating plate 2, so as to feed it back to the electric power adjuster 16. With this, for a time period preset, the heating plate 2 maintains the preset constant temperature, steadily.

Fig. 4 shows other embodiment of the electron bombardment heating apparatus, according to the present invention, wherein the elements, similar to those in the embodiment of the electron bombardment heating apparatus that was shown in Fig. 1 mentioned above, are also given with the same reference numerals thereto. The embodiment of the electron bombardment heating apparatus shown in this Fig. 4 is almost similar to the embodiment of the electron bombardment heating apparatus shown in Fig. 1 mentioned above, and therefore, explanation will be given only about the portions

differing from that. Thus, in the embodiment shown in Fig. 4, the periphery wall portion 13a having a small radius is located down while the periphery wall portion 13b having a large radius up, and they are also connected with each other, by means of the horizontal wall provided therebetween. Comparing to the embodiment shown in Fig. 1 mentioned above, it is possible to achieve the heating panel 2, being wider in an area thereof, as the ceiling of the heated martial supporting member 1.

Fig. 5 shows further other embodiment of the electron bombardment heating apparatus, according to the present invention, wherein the elements, similar to those in the embodiment of the electron bombardment heating apparatus that was shown in Fig. 1 mentioned above, are also give with the same reference numerals thereof.

The higher the temperature of the heating plate 2, the more the thermal loss due to the radiant heat, even if trying to heat up the heating plate 2 through the electrons. Then, it is necessary to increase the number of pieces of the reflectors for reflecting the radiant heat thereupon. In general, for every increase of temperature of one hundred centigrade (100°C) of the heating plate 2, it is necessary to increase the number of pieces of the reflectors 3 by one (1) piece. However, with such the reflectors 3 as shown in Fig. 1 mentioned above, each being made from a metal plate, wiring is needed between them, so as to bring the filaments 9 and the reflectors 3 to be equal in the potential thereof, for the purpose of preventing electricity from discharging towards the heating plate 2 and the opposite side thereof.

Then, for necessitating no such the wiring, as shown in Fig. 5, between a plural numbers of metal reflectors 3 is inserted an insulator plate 20, such as, a ceramic plate, etc., for example, having high insulation and high heat-resistance, thereby insulating the reflectors 3 piled up vertically, from each other. The reflector 3 below the insulator plate 20 is one, being provided

for the purpose of heat insulation, but without electrical connection, while the reflectors 3 above the insulator plate 20 are ones, each having functions of both; i.e., preventing electrons from being discharged to a rear side thereof, and for the heat insulation.

However, in the three (3) embodiments mentioned in the above, the periphery wall of the heated material supporting member 1 is divided into the two (2) stages of the periphery wall portions, being different in the radium thereof, but in particular, by taking easiness or the like in production thereof into the consideration, but it is also possible to divide the periphery wall of the heated material supporting member 1 into three (3) or more stages of the periphery wall portions, being different in the radium thereof. Though an increase of the number of stages of the periphery wall portions brings about an improvement on the property of dispersing the thermal stress thereupon, however on the other hand, it increases fragility thereof with respect to other external force, and therefore, it is the best to divide the periphery wall into two (2) stages, and it may limited up to three (3) stages at the largest.

The present invention may be embodied in other specific forms without departing from the spirit or essential feature or characteristics thereof. The present embodiment(s) is/are therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the forgoing description and range of equivalency of the claims are therefore to be embraces therein.